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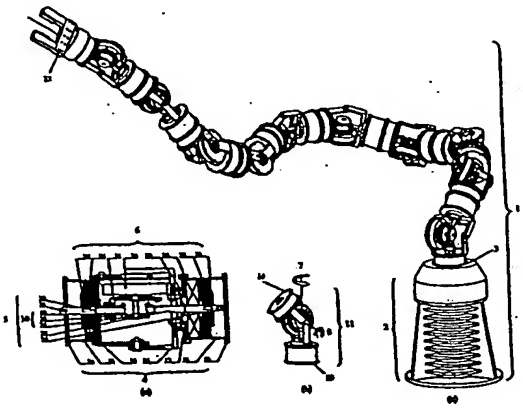

(57) Abstract: The present invention provides an apparatus (1) for carrying various types of tools (12) for the purpose of undertaking welding, painting, manipulation, assembly, material handling, inspection and any desired motions. The apparatus includes a base system (2) having a standardized mechanical and electric interface and providing the output of motion with sufficient power (3), a series of serially connected flexible housing frames (4) enabling the apparatus to execute various configurations (ie, motions), a series of independent motion transmission units (5) enabling the transmission of the single motor's motion along all the motion transmission units, and a series of serially connected motion distribution units (6) enabling the output of motion from a motion transmission unit to its corresponding link. Each flexible housing frame (4) has two degrees of freedom (DOF): one for twisting rotation (7) and the other for pivoting rotation (8). Each motion transmission unit includes two shafts (20 and 25) and a special bevel-gear mechanism (10). The triple (flexible housing frame, motion transmission unit, motion distribution unit) forms a modular entity (11) of the apparatus enabling the apparatus to be easily scaleable (ie, to add or remove modular entities according to the requirement of tasks).

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MODULAR ROBOT MANIPULATOR APPARATUS

DESCRIPTION

Field of Invention

The present invention relates to a modular robot manipulator for carrying tools to fulfill multiple purpose applications such as: welding, painting, manipulation, assembly, material handling, inspection and the execution of any desired motions.

The apparatus has particular application for tasks in a high complex environment such as in-body surgery, in-body medical inspection, and tasks that are not possible with conventional robot manipulators having motor inside each link or flexible housing frame. It should be appreciated, however, that the broad concept of the inventive apparatus is not limited to this particular application, but is applicable to a variety of situations where scalability and single motor driving mechanism are required.

Background of Invention

Robot manipulator is a versatile machine for carrying tools to undertake a variety of tasks ranging from welding, painting, manipulation, assembly, material handling, minimally invasive in-body surgery, minimally invasive in-body inspection, to operation and inspection in various environments. However, the conventional robot manipulators exhibit a number of drawbacks and disadvantages. Some of the drawbacks are as follows:

1. High cost:
   All the robot manipulators are composed of serially connected links. However, all the existing robot manipulators must have one actuator for each link or each degree of freedom. This makes the whole manipulator very heavy and very expensive to build.

2. Poor ratio of payload over weight:
   Because of the weight constraint due to the fact that each link has one actuator inside, the effective output of torque of each actuator can not be fully used to carry the payload at the end of the manipulator. This lost of efficiency causes a serious problem of wastage of energy and severely limits the effective payload of the manipulator. Therefore, the ratio of payload over weight is very poor.

3. Limited flexibility:
   Because of the weight of each link, the number of links that can be serially connected together is largely reduced because the torque output of each actuator has a limit. This results in a reduced number of degrees of freedom (ie, flexibility) that a manipulator can have.

4. Difficulty for miniaturization:
   Because of the difficulty in making a mini or micro electric actuator with meaningful power output, it is extremely difficult to build a mini or micro manipulator if each link requires (at least) one electric actuator to be inside.

In view of the above drawbacks, there is clearly a need to develop a single motor driven manipulator.

Summary of Invention

According to one aspect of the present invention, there is provided a system for carrying tools to undertake welding, painting, manipulation, assembly, inspection and any desired motions, the system including:

a base system having standardized mechanical & electric interface and providing the output of motion with sufficient power;

a series of serially connected flexible housing frames, each having two degrees of freedom and enabling the apparatus to execute various configurations;

a series of serially connected motion transmission units enabling the transmission of the single motor's motion along all the motion transmission units;

a series of independent motion distribution units enabling the output of motion from a motion transmission unit to its corresponding flexible housing frame;

modular entities composed of the triple (flexible housing frame, motion transmission unit, motion distribution unit) enabling the apparatus to be easily scaleable. (ie, to add or remove modular entities according to the requirement of tasks).

In a preferred form of the invention, the base system includes a single electric motor, a reduction gearbox and mechanical & electric interface to the first modular entity of the apparatus.

In a preferred form of the invention, a flexible housing frame includes: (a) two standardized mechanical & electric interfaces at the two ends of the flexible housing frame enabling the easy connection with the previous or subsequent flexible housing frame, (b) the mechanical & electric interface with the corresponding motion distribution unit of the same modular entity, (c) a hinge mechanism supporting the degree of freedom for pivoting rotation, ~~and~~ (d) a cylinder-to-cylinder connection mechanism supporting the degree of freedom for twisting rotation.

In a preferred form of the invention, the motion transmission unit includes two shafts and a special bevel-gear mechanism.

In a preferred form of the invention, the motion distribution unit includes: (a) two clutches, (b) two speed reducers and (c) two brakes. The input of the two clutches are connected to the shafts of the motion transmission unit of the same modular entity while their output are connected to the input of the two speed reducers. Each brake has one end connected to the input of a corresponding speed reducer and the other end connected to the flexible housing frame of the same modular entity.

In a preferred form of the invention, the modular entity includes one flexible housing frame, one motion transmission unit and one motion distribution unit.

Thus, the present invention provides a new type of modular robot manipulator driven by single electric motor. The implementation of this system can enable substantially all of the drawbacks discussed above to be overcome. In particular, the system of the present invention lends itself to the construction of a modular, self-configurable and highly flexible robot manipulator.

By using a single motor driving mechanism, it will be possible to develop a miniaturized version of the modular robot manipulator. In this way, the modular robot manipulator can be applied to a highly constrained and complex environment like inside human-body.

Brief Description of Figures

Fig1 shows the perspective views of a modular Robot Manipulate Apparatus, its modular entity and the full section view of the modular entity.

Fig 2 shows the detail of the full section view of the modular entity of a Modular Robot Apparatus.

Detailed Description of The Invention

Referring to Fig 1(a) and Fig 1(c) of the drawings, the present invention provides an apparatus (1) for carrying a various type of machine tools (12) for the purpose of undertaking manipulation, assembly, material handling, inspection and any desired motions. The apparatus (1) includes:

I. A base (2), having an interface mechanism (3) providing the output of rotary motion with sufficient power;

II. A series of serially connected flexible housing frames (4) enabling the apparatus (1) to execute various configurations and providing the support for the apparatus (1) (similar to the bone supporting human arm);

III. A series of serially connected rotary motion transmission units (5) enabling the transmission of the rotary motion provided by the base (2) along all the motion transmission units, and

IV. A series of serially connected motion distribution units (6) each enabling the output of rotary motion from a motion transmission unit to its corresponding flexible housing frame.

Referring to Fig 1(b) of the drawings, each flexible housing frame of the present apparatus (1) has two degrees of freedom (DOF): one for twisting rotation (7) and the other for pivoting rotation (8).

Referring to Fig 1(b) and Fig 1(c) of the drawings, a modular entity (11) is composed of one flexible housing frame of the present apparatus (1), one motion transmission unit of the present apparatus (1), and one motion distribution unit of the present apparatus (1). In other words, the present apparatus (1) is composed of a series of

serially connected modular entities (11). The number of the modular entities (11) is variable according to a preferred application. This enables the present apparatus (1) to be easily scalable (i.e., to add or remove modular entities).

Referring to Fig 2 of the drawings, the flexible housing frame (4) of the present apparatus (1) includes:

I. A small housing tube (13) on which one end of the corresponding motion distribution unit is fixed, having a standardized interface mechanism (14) at one end to support the connection with the adjacent modular entity (or machine tool if it is the last one);

II. A small folk (15) with its base fixed on the small housing tube (13), having two fingers: one serving as an interface mechanism for the fixture of the corresponding pivoting speed reducer (32), and the other serving as an interface mechanism for the big folk (16) to be hinged on it;

III. A big folk (16) with its base fixed on an interface mechanism (33) to the corresponding twisting speed reducer (34), having two fingers: one fixed on the output side of the corresponding pivoting speed reducer (32) and the other hinged with the small folk (15);

IV. A big housing tube (18) on which the corresponding motion distribution unit is fixed, having a standardized interface mechanism (19) at one end to support the connection with the adjacent modular entity (or machine tool if it is the last one);

V. A cover (17) fixed on the big housing tube (18) providing an interface mechanism enabling the big folk (16) to rotate axially.

Referring to Fig2 of the drawings, the motion transmission unit (5) of the present apparatus (1) includes:

I. One shaft (20), having a standardized interface mechanism (21) at one end to support the connection with the shaft of the adjacent motion transmission unit and the other end fixed on the corresponding bevel-gear mechanism (10);

II. A second shaft (25), having a standardized interface mechanism (26) at one end to support the connection with the shaft of the adjacent motion transmission unit and the other end fixed on the corresponding bevel-gear mechanism (10);

III. A bevel-gear mechanism (10) transmitting the rotary motion between above two shafts (20 and 25) no matter what the angle is between these two shafts (20 and 25).

Referring to Fig 2 of the drawings, the bevel-gear mechanism (10) of the motion transmission unit (5) further includes: two small bevel gears (22 and 23) of equal size (one fixed on one end of the shaft (20) and the other fixed on one end of the shaft (25)), and a big bevel gear (24). The two small bevel gears (22 and 23) are each

engaged with the big bevel gear (24) at the angle of 90 ° without any axial offset.

Referring to Fig2 of the drawings, the motion distribution unit (6) of the present apparatus (1) includes:

I. One clutch (27) having its input side mounted on the corresponding shaft (20) and its output side connected to the corresponding speed reducer (32) through an interface of bevel gear mechanism (31) enabling the transmission of the rotary motion from the corresponding shaft (20) to the corresponding speed reducer (32);

II. A second clutch (30) having its input side mounted on the corresponding shaft (25) and its output side connected to the corresponding speed reducer (34) enabling the transmission of the rotary motion from the corresponding shaft (25) to the corresponding speed reducer (34);

III. Two brakes (28 and 29) each having its one side fixed on the corresponding housing tubes (13 and 18) respectively and the other side connected with the output side of the corresponding clutches (27 and 30) respectively, providing the force to brake the rotary motion of the corresponding speed reducers (32 and 34) respectively when the power is turned on or off;

IV. A speed reducer (32) for pivoting rotation fixed on the corresponding finger small folk (15) having its input connected to the output of the corresponding clutch (27) through an interface of bevel-gear mechanism (31) and its output shaft fixed on the corresponding finger of the big folk (16), providing the torque for the corresponding flexible housing frame (4) to execute pivoting rotation;

V. A speed reducer (34) for twisting rotation having its output connected to the base of the big folk (16) through an interface mechanism (33), providing the torque for the corresponding flexible housing frame (4) to execute twisting rotation.

The apparatus (1) of the present invention is therefore able to carrying a various types of machine tools (12) for the purpose of undertaking manipulation, assembly, material handling, inspection and any desired motions.

It will be appreciated that various modifications, alterations and/or additions may be introduced into the construction and arrangement of the parts of the apparatus (1) particularly herein without departing from the spirit or ambit of the present invention.

CLAIMS

1. An apparatus for carrying a various types of tools for the purpose of welding, painting, manipulation, assembly, material handling, inspection and any desired motions, the apparatus including:

   a base system having standardized mechanical & electric interface and providing the output of motion with sufficient power;

   a series of serially connected flexible housing frames, each having two degrees of freedom and enabling the apparatus to execute various configurations;

   a series of serially connected motion transmission units enabling the transmission of the single motor's motion along all the motion transmission units;

   a series of independent motion distribution units enabling the output of motion from a motion transmission unit to its corresponding flexible housing frame;

   modular entities composed of the triple (flexible housing frame, motion transmission unit, motion distribution unit) enabling the apparatus to be easily scaleable. (ie, to add or remove modular entities according to the requirement of tasks).

2. An apparatus as claimed in Claim 1 wherein the base system includes a single electric motor, a reduction gearbox and mechanical & electric interface to the first modular entity of the apparatus.

3. An apparatus as claimed in Claim 1 wherein the flexible housing frame includes: (a) two standardized mechanical & electric interfaces at the two ends of the flexible housing frame enabling the easy connection with the previous or subsequent flexible housing frame, (b) the mechanical & electric interface with the corresponding motion distribution unit of the same modular entity, (c) a hinge mechanism supporting the degree of freedom for pivoting rotation, and (d) a cylinder-to-cylinder connection mechanism supporting the degree of freedom for twisting rotation.

4. An apparatus as claimed in Claim 1 wherein the motion transmission unit includes two shafts and a special bevel-gear mechanism.

5. An apparatus as claimed in Claim 1 wherein the motion distribution unit includes: (a) two clutches, (b) two speed reducers and (c) two brakes. The input of the two clutches are connected to the shafts of the motion transmission unit of the same modular entity while their output are connected to the input of the two speed reducers. Each brake has one end connected to the input of a corresponding speed reducer and the other end connected to the flexible housing frame of the same modular entity.

6. An apparatus as claimed in Claim 1 wherein the modular entity includes one flexible housing frame, one motion transmission unit and one motion distribution unit.

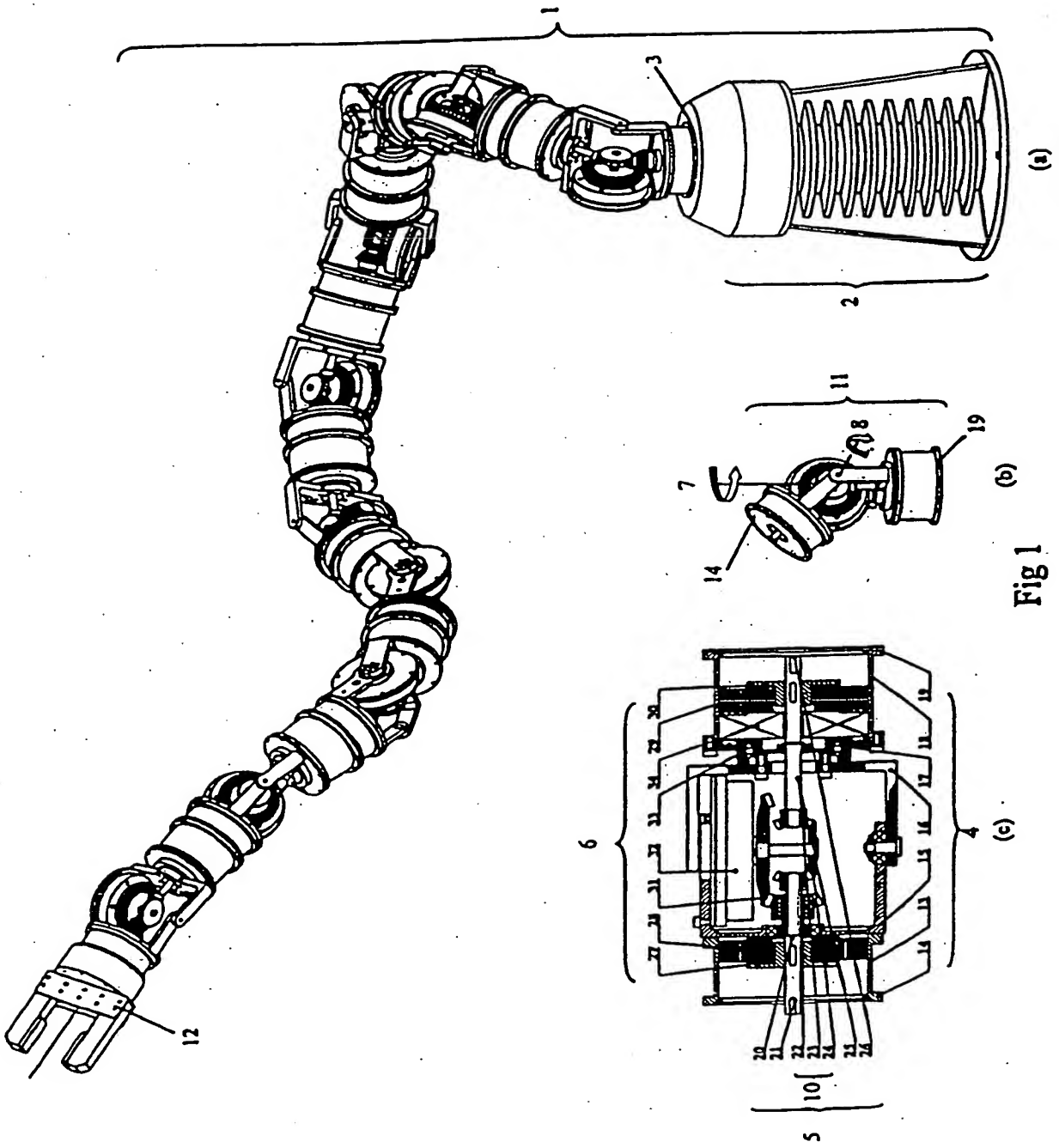

Fig 1

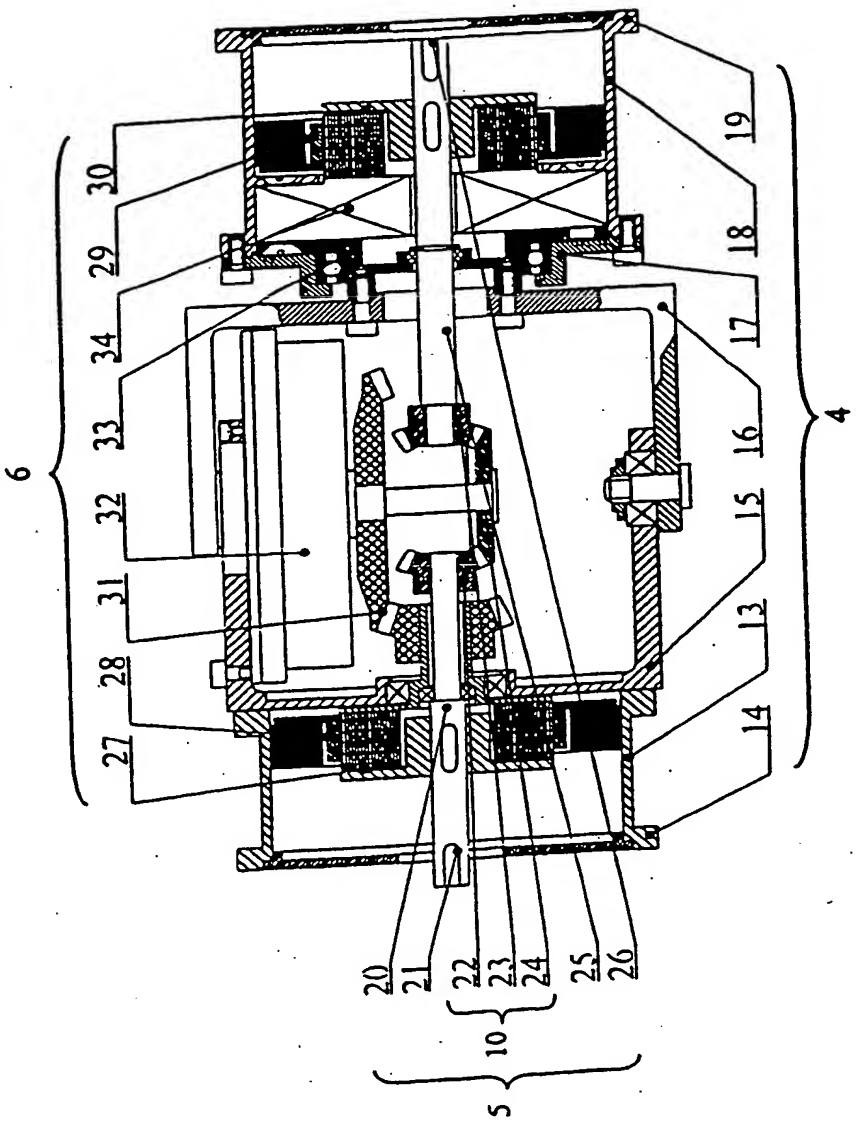

Fig 2